MARS RADAR OBSERVATIONS WITH THE GOLDSTONE SOLAR SYSTEM RADAR. A. F. C. Haldemann[1], R. F. Jurgens[1], K. W. Larsen[2], R. E. Arvidson[2], and M. A. Slade[1], [1] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109-8099, USA. [2]Dept. of Earth and Planetary Sciences, Washington University, 1 Brookings Drive, St. Louis, MO 63130. Email: albert@shannon.jpl.nasa.gov.

Introduction: The Goldstone Solar System Radar (GSSR) has successfully collected radar echo data from Mars over the past 30 years. As such, the GSSR has played a role as a specific mission element within Mars exploration. The older data provided local elevation information for Mars, along with radar scattering information with global resolution (e.g. [1,2]). Since the upgrade to the 70-m Deep Space Network (DSN) antenna at Goldstone completed in 1986, Mars data has been collected during all but the 1997 Mars opposition. Radar data, and non-imaging delay-Doppler data in particular, requires significant data processing to extract elevation, reflectivity and roughness of the reflecting surface [3]. The spatial resolution of these experiments is typically some 20 km in longitude by some 150 km in latitude. The interpretation of these parameters while limited by the complexities of electromagnetic scattering, do provide information directly relevant to geophysical and geomorphic analyses of Mars.

Landing Site Assessment with Radar Data. The usefulness of radar data for Mars exploration has been demonstrated in the past. Radar data were critical in assessing the Viking Lander 1 site [4, 5] as well as, more recently, the Pathfinder landing site [6, 7]. In general, radar data have not been available to the Mars exploration community at large. A project funded initially by the Mars Exploration Directorate Science Office at the Jet Propulsion Laboratory (JPL), and later funded by NASA's Mars Data Analysis Program has reprocessed to a common format a decade's worth of raw GSSR Mars delay-Doppler data in aid of landing site characterization for the Mars Program. These data will soon be submitted to the Planetary Data System (PDS). The radar data used were obtained between 1988 and 1995 by the GSSR, and comprise some 63 delay-Doppler radar tracks. Of these, 15 have yet to be recovered from old 9-track tapes, and some of the data may be permanently lost. The available data used for Mars Exploration Rover landing site analysis for example, are listed in Table 1.

Enhanced Radar Observations: Two modern radar techniques offer the opportunity to improve the spatial resolution and the global coverage of available radar data: random-long-code delay-Doppler observations, and interferometric delay-Doppler observations.

Random-long-code delay-Doppler radar. In standard delay-Doppler observations, Mars is overspread [8]. This can be overcome by using a pseudo-random, non-repeating code that is much longer than the observing run. This technique was successfully applied to Mars by Harmon et al. [9] to image the Martian surface at 39 km resolution with the Arecibo Observatory at 12.6 cm wavelengths. The GSSR used the technique at 3.5 cm during the 1999 opposition [10]. Dual-polarization coded long pulse data were collected. The 1999 opposition provided the opportunity to observe Mars at high northern sub-radar latitudes, providing a good view of the north polar region. The campaign resulted in 14 days of data over the course of a month. The GSSR 25 kHz baud rate used in 1999 had the potential to produce 12 km resolution cells in the polar regions. For signal-to-noise reasons, the actual cell size was 48 km. The random-long-code technique is particularly useful for obtaining radar information away from the sub-Earth radar track at moderate to high latitude. The north-south ambiguity inherent in delay-Doppler is still manifest, and so the technique really lends itself to observations of bright features on the surface.

Interferometric delay-Doppler radar. Observing the radar echo with more than one receiver provides a means to remove the north-south delay-Doppler ambiguity. Ten of the 63 radar tracks in the recently re-assembled radar dataset are interferometric radar tracks. The interferometric information has never been processed, because the signal to noise is insufficient to constrain both the phases and the radar scattering parameters. The new topographic data from the Mars Orbiter Laser Altimeter (MOLA) on the Mars Global Surveyor (MGS) spacecraft offer the best means to analyze these unused data to make radar maps that extend the radar properties coverage some 3 to 4 degrees beyond the sub-earth radar track. This will be a significant expansion of the dataset, and is all the more warranted as the radar spatial resolution improves away from the sub-Earth track (smaller range ring-Doppler strip intersections away from the sub-Earth track). At the outer edges the radar resolution cell

is of the same order of size as the landing site ellipses for future mission (approximately 20 km diameter). Progress on this new technique is reported by Larsen et al. at this meeting, in particular as regards data acquired during the 2001 Mars opposition.

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Acknowledgments: The research described above was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Table 1. Existing GSSR Mars Radar Data for MER

Date	Lat. (deg.)	West Longitude (deg.) Rise	Set
14 Sept 1990	-6.0	242	289
22 Sept 1990	-4.8	160	214
29 Sept 1990	-4.0	108	131
2 Oct 1990	-3.8	52	109
12 Oct 1990	-3.3	41	89
25 Oct 1990	-3.6	227	242
27 Oct 1990	-3.7	234	286
20 Nov 1990	-7.6	65	82
15 Dec 1990	-12.0	53	92
17 Dec 1990	-12.2	23	77
24 Dec 1990	-12.8	319	20
28 Dec 1990	-13.0	290	6
30 Dec 1990	-13.1	263	313
15 Dec 1992*	11.0	214	238
22 Dec 1992*	10.0	192	218
31 Dec 1992*	8.6	158	207
2 Jan 1993*	8.2	150	188
3 Jan 1993*	8.0	90	175
5 Jan 1993*	7.7	19	68
10 Jan 1993*	6.8	15	109
14 Jan 1993	6.0	308	353
21 Jan 1993	5.1	239	273
23 Jan 1993*	4.9	186	238
28 Jan 1993*	4.4	137	179
31 Jan 1993*	4.0	99	172
3 Feb 1993*	3.9	102	168
7 Feb 1993*	3.8	109	187
14 Feb 1993*	3.7	8	113

* Interferometric data recorded

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